

# REPORT ON RAT-FLEA INVESTIGATION\*

BY

R. NEWSTEAD, F.R.S.

AND

ALWEN M. EVANS, M.Sc.

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## INTRODUCTION

The investigation was carried out in conjunction with Dr. E. W. Hope, Medical Officer of Health for the City of Liverpool, and his Assistant, Dr. W. Hanna, whose material assistance has made it possible for us to carry it to a successful conclusion.

The object of the investigation was to determine the distribution of the various species of fleas occurring on the rats in the Port and City of Liverpool, with special reference to those species which are responsible for the transmission of plague from rat to rat and from rat to man.

The period during which the investigation was carried out extended from April 12th, 1920, to April 12th, 1921, rats being examined daily five times each week, except during the month of August and from December 22nd, 1920, to January 12th, 1921.

## TECHNIQUE

As a preliminary to these investigations, field observations were conducted as to the general methods adopted by the professional rat catchers in the capture of the animals on board ship and in the city.

It was then decided that the rats sent to the laboratory for examination were to be taken alive from the traps, and placed singly in strong calico bags. The bags were subsequently placed in a lethal chamber, where they remained until the rats and the fleas upon them were dead. This method ensured that all the fleas living on each rat at the time of capture were secured. It was further

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decided that, as far as possible, only rats caught singly in traps were to be sent to the laboratory, because it was seen that, when a number of rats are together in one trap, sweating is apt to occur, with the result that the fleas leave the rats before the latter are captured.

### LABORATORY METHODS

The fleas were collected from each bag and rat, over a sheet of white paper, and placed in a numbered watch-glass containing glycerine. In this medium they were arranged in rows on a slide, and identified by microscopical examination.

### DEFINITION OF ZONES

ZONE I.—SHIPS. The number of ships from which rats were received was one hundred and twenty-five. The ports from which the ships sailed are named in Table I (*vide infra*).

ZONE II.—DOCKS, ETC. This Zone comprises that part of the Port of Liverpool lying west of a certain line, which defined as accurately as possible the eastward boundary of the warehouse area of the Port.

(a) *Docks*. This section of Zone II is limited to the wharves themselves and the sheds actually situated on the Docks.

(b) *Warehouses*. This section includes the rest of Zone II; the majority of the buildings, from which rats were received, were warehouses.

ZONE III.—CITY. All of the City east of the line bounding Zone II is included in this Zone.

### THE SPECIES OF RATS

No attempt is made to separate the varieties of the species *Mus rattus* and *Mus norvegicus*. *Mus rattus* and its varieties are included under the heading 'black rat,' and *Mus norvegicus* and any varieties are referred to as 'brown rats.'

As will be seen from the following table, all the rats received from ships were black. In Zone IIA the black rats outnumbered the brown

TABLE I.

Showing the number of rats received from ships sailing from the various ports.

Region	Port	No. of rats
Mediterranean ... ..	Alexandria ... ..	64
	Constantinople ... ..	5
	Costanza ... ..	2
	Genoa ... ..	5
	Salonika ... ..	4
		80
India, Ceylon, E. Indies, Burma ...	Bombay* ... ..	5
	Calcutta* ... ..	18
	Colombo* ... ..	4
	Rangoon* ... ..	47
	Java* ... ..	1
		75
East Africa ... ..	Beira* ... ..	1
	Mombasa* ... ..	3
	Various Ports ... ..	1
		5
West Coast of Africa ... ..	Various Ports ... ..	59
West Coast of S. America ... ..	Valparaiso ... ..	5
	Callao ... ..	13
	Coronel ... ..	18
	Pisco* ... ..	3
	Talcahuano ... ..	3
		33
		75
Brazil ... ..	Bahia* ... ..	1
	Pernambuco* ... ..	18
	Rio de Janeiro* ... ..	13
	Rio Grande ... ..	5
		37
Argentine ... ..	Buenos Aires ... ..	53
	R. Plate ... ..	17
	Rosario ... ..	15
		85
North America ... ..	Galveston ... ..	14
	New Orleans ... ..	40
	New York ... ..	1
		55

\* Within the Tropics.

rats by nearly five to one. In Zone IIB, the black rats were much more numerous than the brown rats. In Zone III, however, the position is more than reversed, the brown rats being nearly nine times as numerous as the black rats.

TABLE II.  
Showing the distribution of black and brown rats.

Zone	Black rats	Brown rats	Total
I ... ..	469	—	469
IIA ... ..	24	5	29
IIB ... ..	442	274	716
III ... ..	20	179	199
TOTALS ... ..	955	458	1,413

TABLE III.  
Showing distribution of the various species of fleas.

Zone	<i>Xenopsylla cheopis</i>	<i>Ceratophyllus fasciatus</i>	<i>Ceratophyllus londiniensis</i>	<i>Leptopsylla musculi</i>	<i>Ctenocephalus Canis</i>	Totals
I ... ..	489	219	—	8	—	706
IIA ... ..	10	75	—	9	—	94
IIB ... ..	60*	1,510	3	326	—	1,899
III ... ..	3	320	12	10	1	346
TOTALS ... ..	562	2,124	15	353	1	3,045

\* This figure includes 56 specimens from No. 32 T— Street.

## OBSERVATIONS ON THE VARIOUS SPECIES OF FLEAS FOUND

### *Xenopsylla cheopis*, Rothschild.

The Indian Plague flea is 'the common rat flea of the tropics' (Rothschild, 1910). It is prevalent also in sub-tropical countries, and 'is common during summer and autumn in some of the warmer parts of the temperate zone, more especially in ports which have maritime intercourse with the tropics' (Chick and Martin, 1911). It has been demonstrated experimentally by Bacot (1914) that temperatures below 40° F. are fatal to all but the imaginal stages

of this species. Its almost complete absence from more northern latitudes is therefore attributed to the low winter temperatures which prevail there. In England, *X. cheopis* has been recorded from a brown rat at Plymouth (one specimen) (Rothschild, 1905); from a plague-infected brown rat at Bristol (two specimens), 1916, taken in a rag factory that was the seat of an outbreak of plague; and in 1911 from Guy's Hospital, London, where the species had established itself on a colony of brown rats. In the last case, it was found that the infested rats were living in an artificially heated environment, beneath the laboratory, and the presence of this, the first flourishing colony of *X. cheopis* to be found in England, was attributed to this fact.

SEASONAL VARIATION (Chart II and Table VII). Zone I is the only Zone from which a sufficient number of specimens of *X. cheopis* have been found to allow of any deductions as to seasonal variation. The curve, Chart II, has no very well marked characteristics; the highest point reached, June, 1920, rises from low figures in both May and July. The months September, October, November, show a second but not so great elevation, falling to the lowest figure in December.

In view of the prophetic statement put forward by Chick and Martin (1911, p. 125), it is interesting to observe that we have found a number of *X. cheopis* on the ship rats during every month in the year, the lowest being 0.30 in December, 1921, and the highest 2.18 in June—not in September, as might have been expected.

Owing to the large numbers of *Xenopsylla cheopis* which occur on ship rats, it would appear likely that this species might be present on some of the rats found in the dock sheds. This was found to be the case; out of the twenty-four rats received from Zone IIA, three were found to carry *X. cheopis*. The data were as follows:—

TABLE IV.

No.	Date	RAT		Building	<i>X. cheopis</i>
		Black	Brown		
127	31.v.20	1	—	S. H— Dock	2
148	7.vi.20	1	—	S. C— Dock	7
192	23.vi.20	—	1	C— Dock	1
TOTAL	...	2	1		10

In Zone IIB and Zone III, apart from the colony of *X. cheopis* found in T— Street, which is dealt with in a separate section, isolated specimens of this species were found in a few cases. The data are as follows:—

TABLE V.

## Zone IIB.

No.	Date	RAT		Building	<i>X. cheopis</i>
		Black	Brown		
1019	21.i.21	—	1	14 C— Street	1
1127	10.ii.21	—	1	29 C— Street	1
1135	11.ii.21	—	1	27 K— Street	1
1417	12.iv.21	—	1	M— Mills	1
TOTAL	...	0	4		4

## Zone III.

No.	Date	RAT		Building	<i>X. cheopis</i>
		Black	Brown		
1068	31.i.21	—	1	5 B— Road	1
1401	8.iv.21	1	—	W— Village	2
TOTAL	...	1	1		3

*Ceratophyllus fasciatus*, Bosc.

This is the common rat flea of temperate countries. In the rural districts of Suffolk and North Essex, Strickland and Merriman (1913) found this species to comprise 60 per cent. of the flea population of rats. Our figures show a much higher percentage of *C. fasciatus* for the city of Liverpool:—78 per cent. in Zone IIB and 92 per cent. in Zone III.

SEASONAL VARIATION (Chart III and Table VII). The curve of frequency for Zone IIB reaches a markedly high level during the summer months, with elevations in May-June and again in

September. A distinct depression occurs in July. The temperature curve (Chart I), on the other hand, is considerably higher in this latter month than in May. In September it is lower than in July. The frequency curve for Zone III is based on a much smaller number of records than that for Zone IIB, but with one exception it possesses the same characteristics as the latter. The exception occurs in January, when it rises to 4:11. This high figure is due to the occurrence of two very heavily infested rats among a total of nine. The average infestation of the other seven rats was only 0·7. It is apparent that there are two periods of maximum prevalence of the species, one in early summer, and a second in September. (The latter may possibly begin during August.) These periods both occur during the warmer half of the year, but the lack of detailed correlation between the frequency and temperature curves makes it clear that in Liverpool the prevailing atmospheric temperature has not such a direct influence on the prevalence of the species, as results obtained elsewhere in this country have suggested.

There is no correlation between the curves of average humidity and frequency of *C. fasciatus*. It must be noted, however, that the former is based on records taken in the open, and that the atmospheric humidity probably differs considerably in the buildings, sewers, etc., frequented by rats.

HOSTS. All the rats from Zone I were black, therefore no comparison between the number of fleas found on the different species of rats can be made for this Zone. In Zone II the infestation of brown rats with *C. fasciatus* was rather heavier than that of the black rats.

#### *Leptopsylla musculi*, Dugès

This is a widely distributed species naturally parasitic on mice (*Mus musculus*), but frequently found on rats where the latter inhabit buildings, etc., frequented by mice. This species is a proved potential carrier of plague bacillus, and 'a small percentage' will, according to Bacot (1919), 'bite man under certain conditions.' Strickland and Martin (1913) found it to comprise a very small percentage of the flea fauna of rats in East Suffolk and North Essex, only three specimens being taken in all. Bacot (1919), however, considers that this species may be more prevalent in England than

this figure suggests. As the following figures show, this is the case in the city of Liverpool:—

				per cent. <i>L. musculi</i> .
Zone IIA	...	...	...	9·7 per cent. of total.
Zone IIB	...	...	...	17·2 „ „
Zone III	...	...	...	2·8 „ „

SEASONAL VARIATION (Chart IV and Table VII). The curve shows that the species is most prevalent in Zone II during the months of June-September, after which the numbers fall away to almost zero during December-April. This curve agrees largely with that for *C. fasciatus* in Zone IIB, but the rise takes place a month later, and the disappearance during the winter months is more complete. As in the case of *C. fasciatus*, the curve rises to a high level during September in spite of the drop in temperature during this month.

HOSTS. The numbers of *L. musculi* per rat were almost equal on the two species, the averages were:—

Zone II.—Brown rat	...	Number of fleas per rat	0·41
Black rat	...	„ „ „	0·48
„ III.—Brown rat	...	„ „ „	0·05
Black rat	...	„ „ „	0·05

#### *Ceratophyllus londiniensis*, Roths.

This species is said to be 'A rare Mediterranean species, probably introduced by port rats, has occurred in the house mouse (*Mus musculus*), and possibly on the brown rat (*Epinomys norvegicus*) in London, Dover and Aberdeen.' (Rothschild, 1911.)

Its distribution in Liverpool is interesting; apart from two isolated cases in Zone II, the records, four in all, came from a certain area, where the species appears to have established itself.

#### *Ctenocephalus canis*, Curtis

The common dog flea. This species has frequently been recorded from rats, sometimes in large numbers. It was therefore surprising to find only one specimen, which occurred on a brown rat from Zone III.



*Ctenophthalmus agyrtes*, Heller

Strickland and Merriman, and Nuttall and Strickland, working in rural districts of East Anglia, found this species to comprise a large proportion of the rat fleas in this part of England. Our records, however, show a complete absence of this species. Rothschild (1915) states that this species occurs on the 'brown rat . . . living in the fields, and on the bank vole . . . the common shrew . . . and others.' It is not, therefore, surprising that it is not found on rats in such an urban district as the City of Liverpool. Further, ten other species of Pulicidae, which are recorded by the above-named authors, from rats in East Anglia, and which are naturally parasitic on birds and small wild mammals, are likewise absent from our records.

**PERMANENT BREEDING PLACES OF *XENOPSYLLA CHEOPIS***

On the last day of January, 1921, a specimen of *X. cheopis* was found on a brown rat from No. 32, T— Street. We requested that more rats should be sent from this building, and altogether we received during the first half of February thirteen *brown* rats from which no fewer than fifty-six *X. cheopis* were taken. The records were as follows:—

TABLE VI.

No.	Date	Brown	<i>X. cheopis</i>	<i>C. fasciatus</i>
1067	31.i.21	1	1	—
1087	3.ii.21	1	5	2
1094	4.ii.21	1	5	7
1095	4.ii.21	1	5	4
1096	4.ii.21	1	9	4
1097	4.ii.21	1	7	2
1103	7.ii.21	1	6	0
1104	7.ii.21	1	2	8
1105	7.ii.21	1	6	4
1106	7.ii.21	1	1	0
1107	7.ii.21	1	3	4
1108	7.ii.21	1	5	2
1133	11.ii.21	1	1	—
<b>TOTAL</b>		13	56	37

Average *X. cheopis* per rat = 4.3.

There can be no doubt that here at T—— Street is a second 'flourishing colony of *X. cheopis* in the British Islands.' As in the case of the first such colony to be discovered (Rothschild, 1911), its existence is probably to be attributed to the fact that its hosts were living in an artificially heated environment.

Beneath the middle of the roadway adjoining the premises T—— Street runs a steam culvert. The excavations, which it was possible to make, revealed that the rat burrows lead in the direction of the culvert. It was, therefore, thought probable, that the nests

TABLE VII.

Showing the average frequency during each month of the common species in the zones in which they occur.

Date	Average Mean Temperature	Average Humidity	ZONE I		ZONE II (b)		ZONE III	
			<i>Xenopsylla cheopis</i>	<i>Ceratophyllus fasciatus</i>	<i>Ceratophyllus fasciatus</i>	<i>Leptopsylla musculi</i>	<i>Ceratophyllus fasciatus</i>	
1920—								
April ..	46·3°	73	0·33	1·75	12·66*	0·0	No rats received	
May ...	52·9°	74	0·59	0·90	5·38	0·32	"	
June ...	57·8°	73	2·18	0·40	3·28	1·84	3·27	
July ...	57·2°	79	0·51	0·16	2·70	0·89	1·07	
August ...	56·4°	80	Investigation suspended.					
September	55·5°	81	1·58	0·0	5·17	1·83	2·24	
October ...	51·1°	84	1·75	0·22	1·82	0·46	1·09	
November...	45·8°	83	1·18	0·37	1·61	0·41	0·68	
December	40·5°	86	0·30	0·09	1·29	0·06	0·58	
1921—								
January ...	46·0°	84	0·48	0·03	1·19	0·04	4·11*	
February ...	41·1°	84	0·93	0·75	1·33	0·04	1·27	
March ...	45·5°	79	0·90	0·70	1·08	0·07	1·00	
April ...	46·7°	74	1·00	—	0·61	0·09	0·40	

\* Based on a very small number of records.

of the rats were situated in the near neighbourhood of the steam culvert, and as the temperature of the latter was found on 21.2.21 to be  $105^{\circ}$  F., the area surrounding it for a considerable distance must be maintained at a temperature higher than the normal. Unfortunately it was impossible to trace the burrows far enough to discern whether the nests were actually within the area influenced by the steam culvert, and, therefore, the suggested explanation of the presence of this colony of *X. cheopis* can only be regarded as an extremely probable one.

### SUMMARY

1. Five species of fleas were found to occur on rats from the ships, Port, and City of Liverpool. They were:—*Xenopsylla cheopis*, *Ceratophyllus fasciatus*, *Leptopsylla musculi*, *Ceratophyllus londiniensis*, and *Ctenocephalus canis*.

2. *Xenopsylla cheopis* occurred freely on ship rats throughout the whole period of the investigation. It was also found on three rats from the dock sheds, and isolated specimens were found on four rats from Zone IIB, and on two rats from Zone III. A permanent breeding place of the species was discovered in certain premises in Zone IIB.

3. *Ceratophyllus fasciatus* was universally prevalent during the whole course of the investigation. The number of fleas per rat was greatest during the summer months, but the curve of frequency could not be correlated in detail with that of the average temperature.

4. *Leptopsylla musculi* was most prevalent on rats from Zone II. It occurred very rarely upon ship rats. *Ceratophyllus londiniensis* was found rarely in Zones II and III, and of *Ctenocephalus canis* one specimen was taken in Zone III.

CHART I

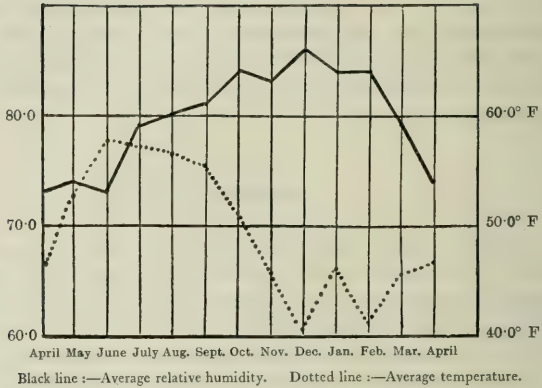
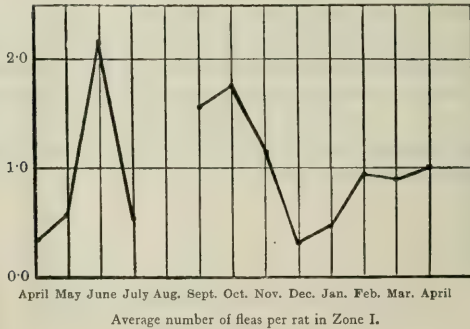
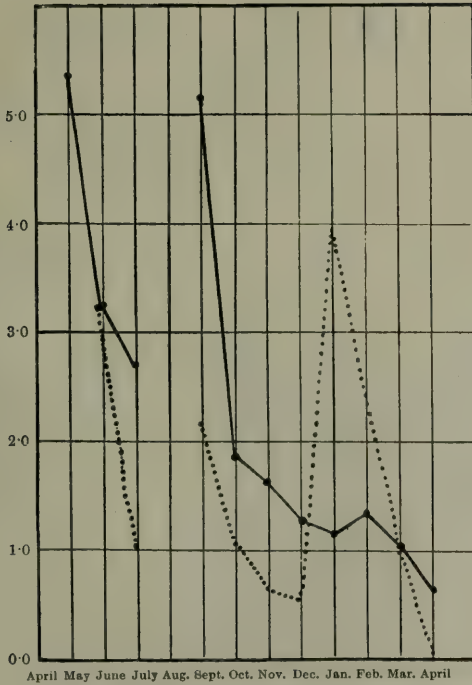
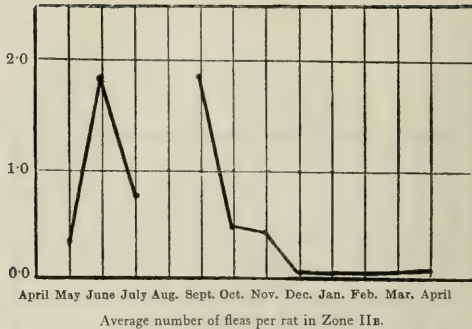
CHART II. *Xenopsylla cheopis*

CHART III. *Ceratophyllus fasciatus*

Black line:—Average number of fleas per rat in Zone II.

Dotted line:—Average number of fleas per rat in Zone III.

CHART IV. *Leptopsylla musculi*

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